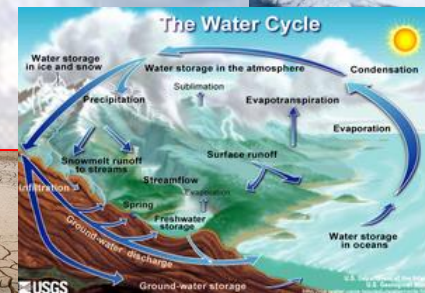
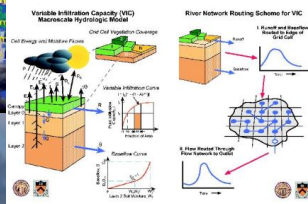
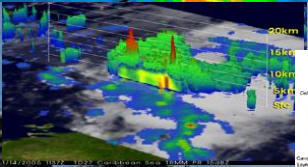
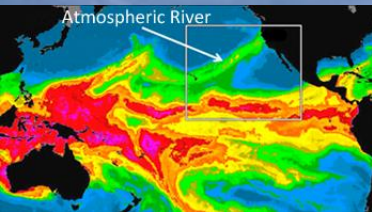




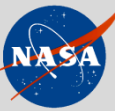
# Observation, modeling, and prediction of natural hazards: Remote sensing perspective

**Ali Behrangi**

*NASA Jet Propulsion Laboratory,  
California Institute of Technology*



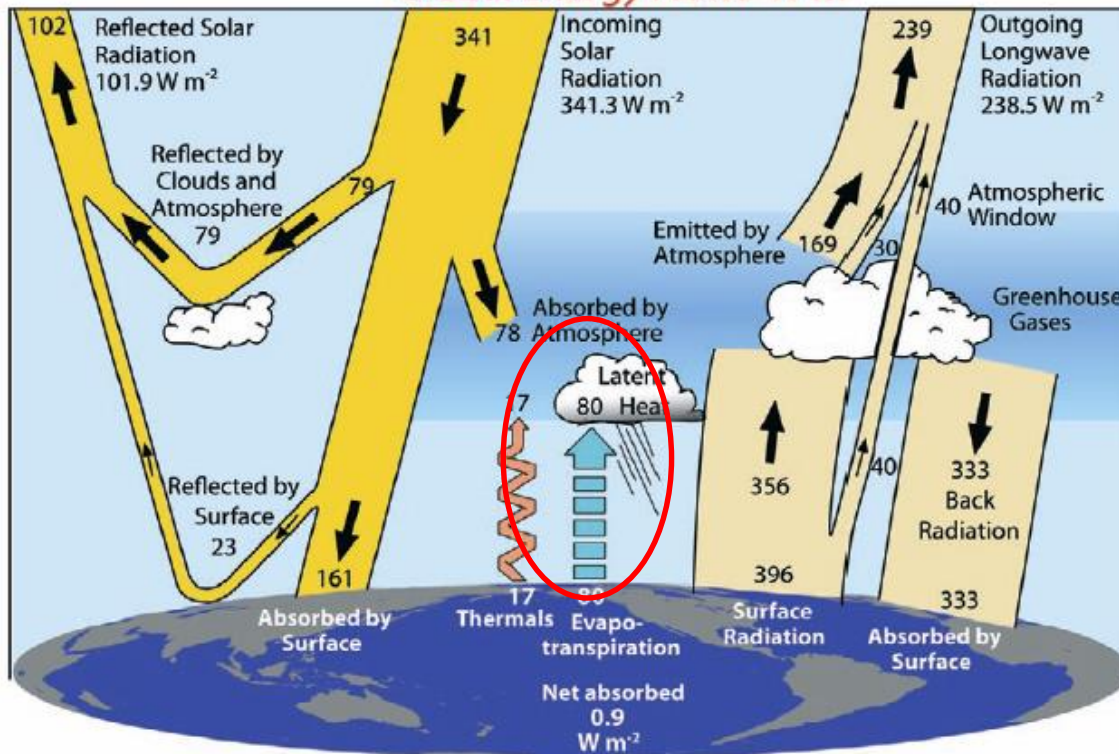
# Weather and climate extremes and water cycle



## WATER CYCLE

Condensation

Global Energy Flows  $\text{W m}^{-2}$

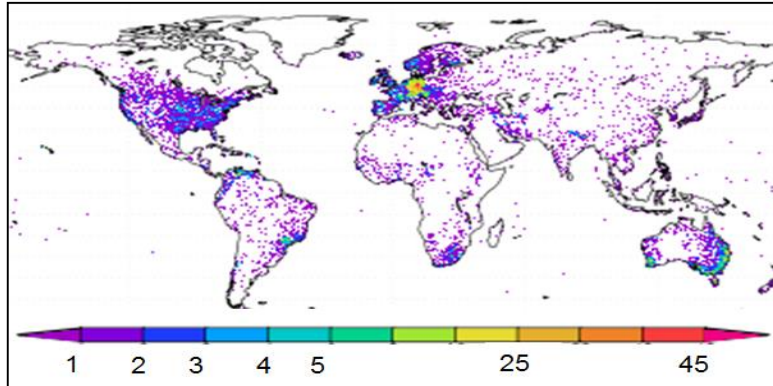


Precipitation

Surface Runoff

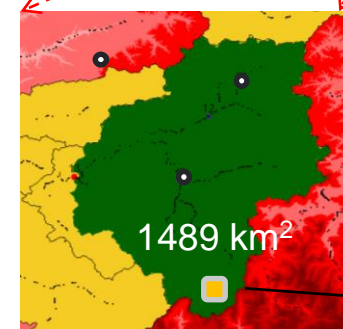
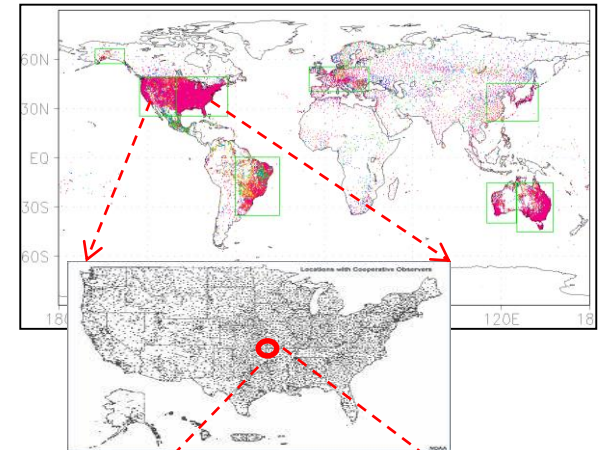
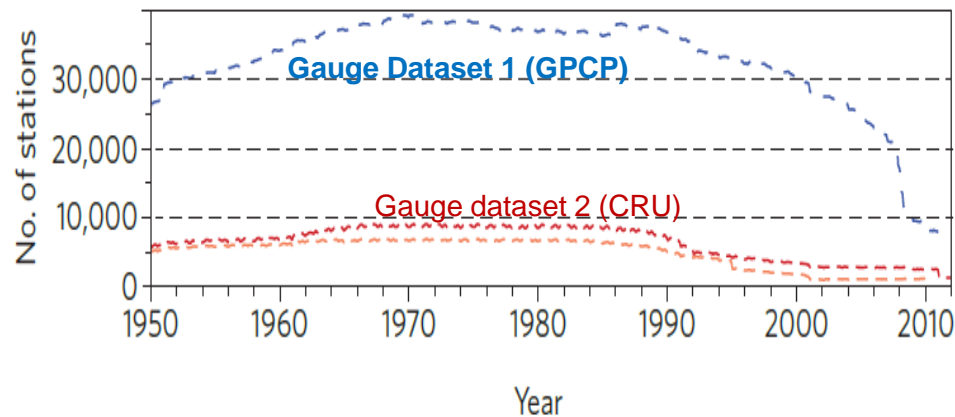
# Precipitation SPATIAL resolution/coverage need for hydrology

Number of rain gauges in a  $0.5^\circ \times 0.5^\circ$  grid box (GPCC)



Ocean and polar regions virtually NOT sampled

Number of ground stations are decreasing



Only 2 gauges inside !

Mid-size university

# Earth Science Missions

## ISS Instruments

CATS, LIS, SAGE III  
TSIS-1, OCO-3, ECOSTRESS, GEDI  
CLARREO-PF

## JPSS-2 Instruments

RBI, OMPS-Limb

- Formulation
- Implementation
- Primary Ops
- Extended Ops

## Evapotranspiration

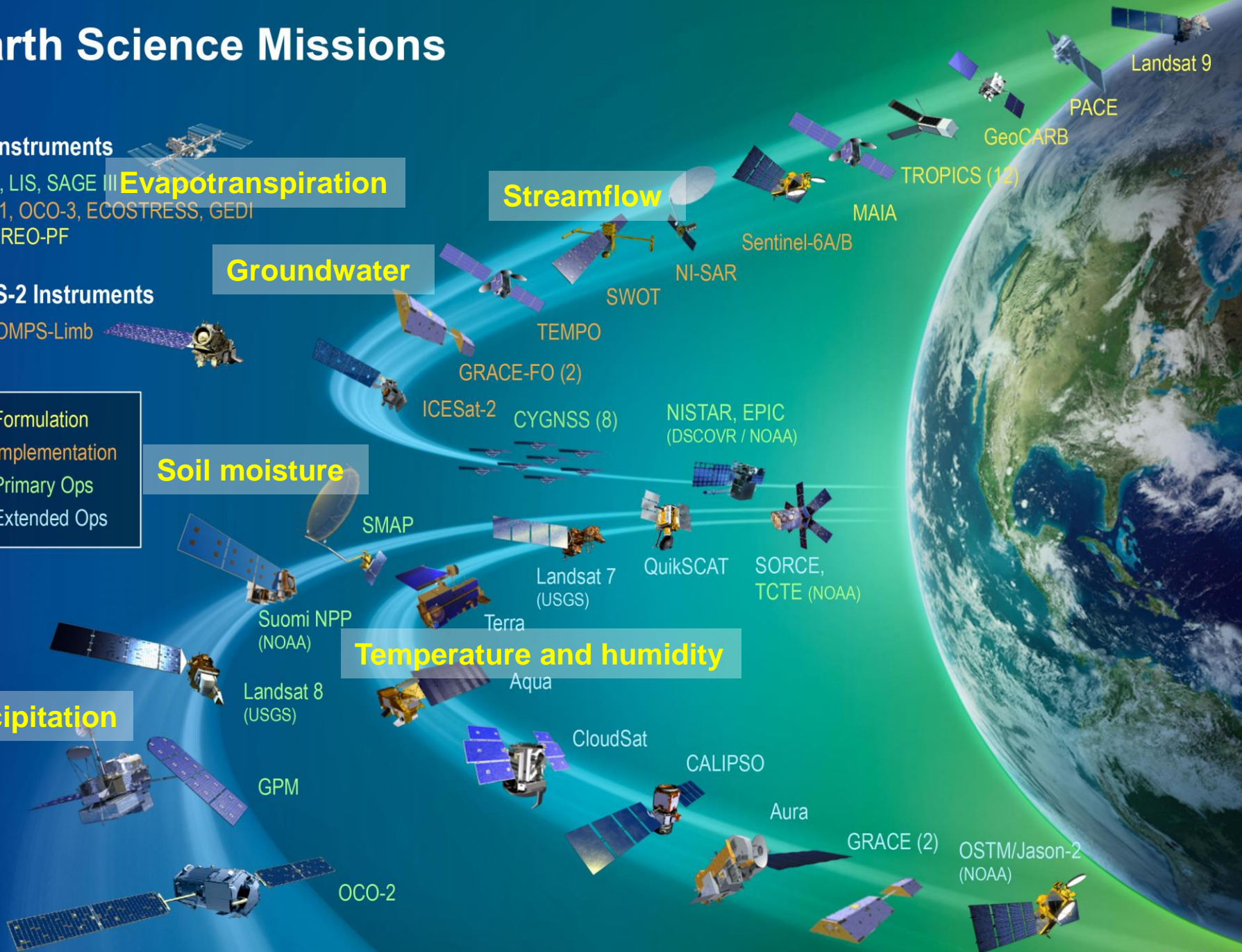
## Groundwater

## Streamflow

## Soil moisture

## Temperature and humidity

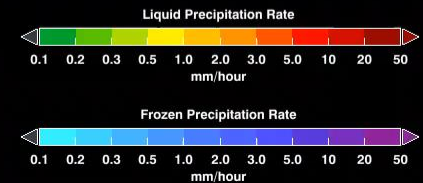
## Precipitation



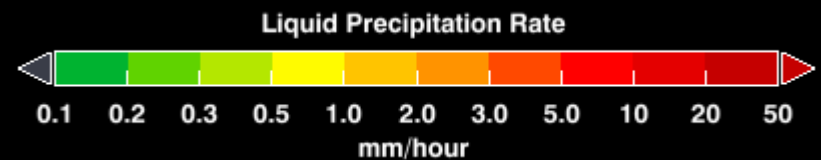
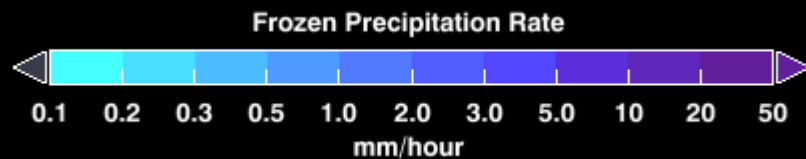
# Precipitation estimation from space



7/25/2014 00:55



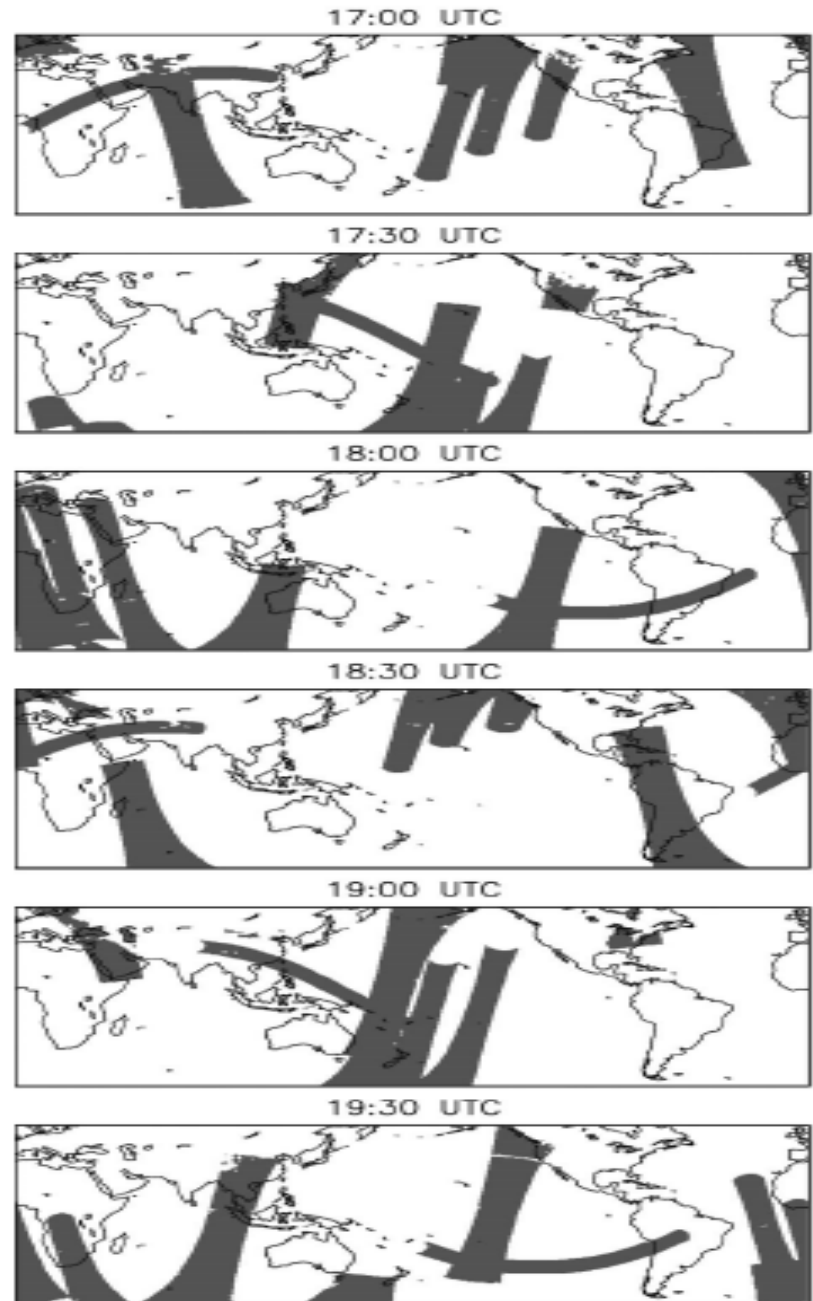
# April 1, 2017 – Radar on the Global precipitation measurement (GPM) mission



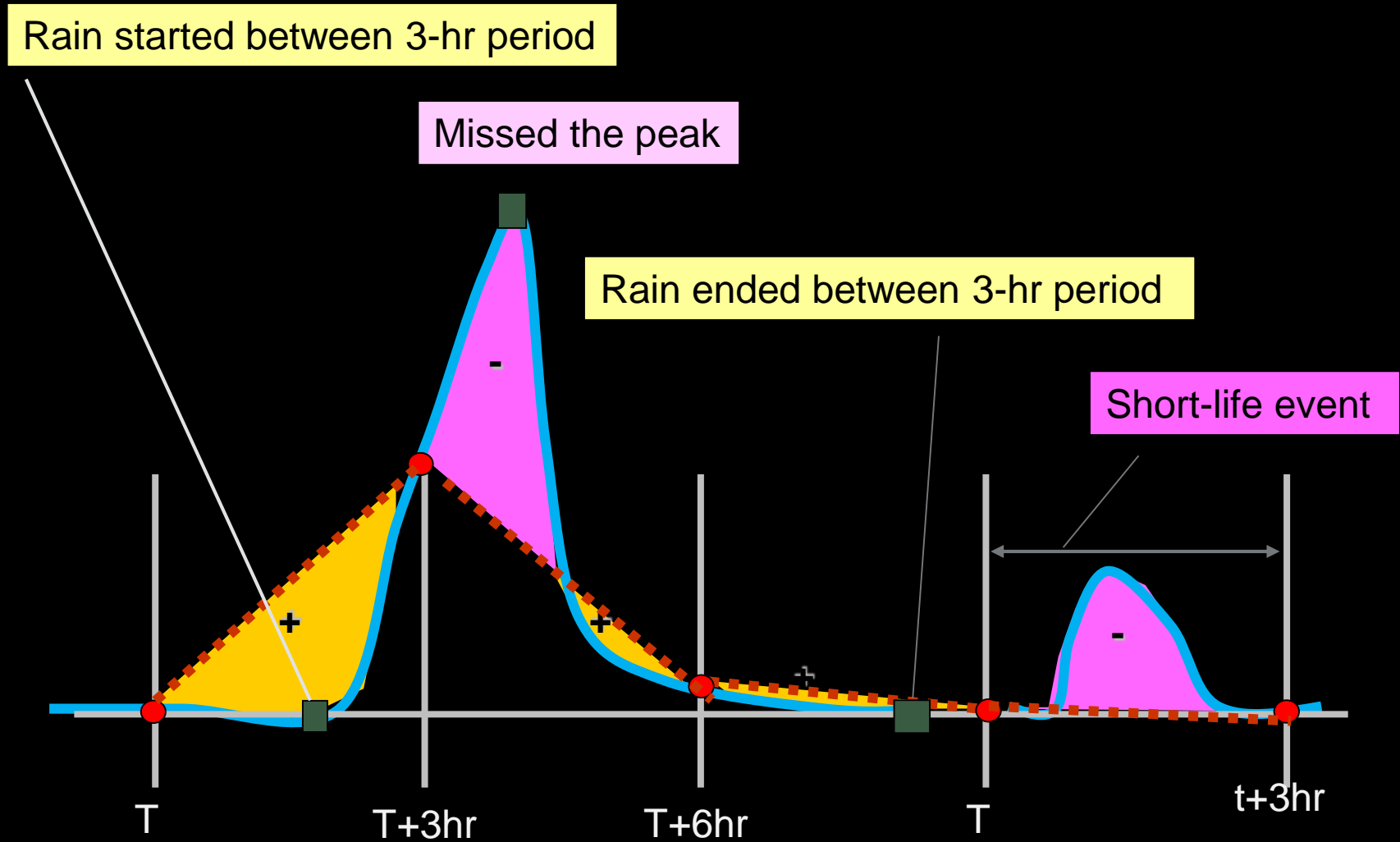
*Credit: NASA GSFC*

# Challenge !

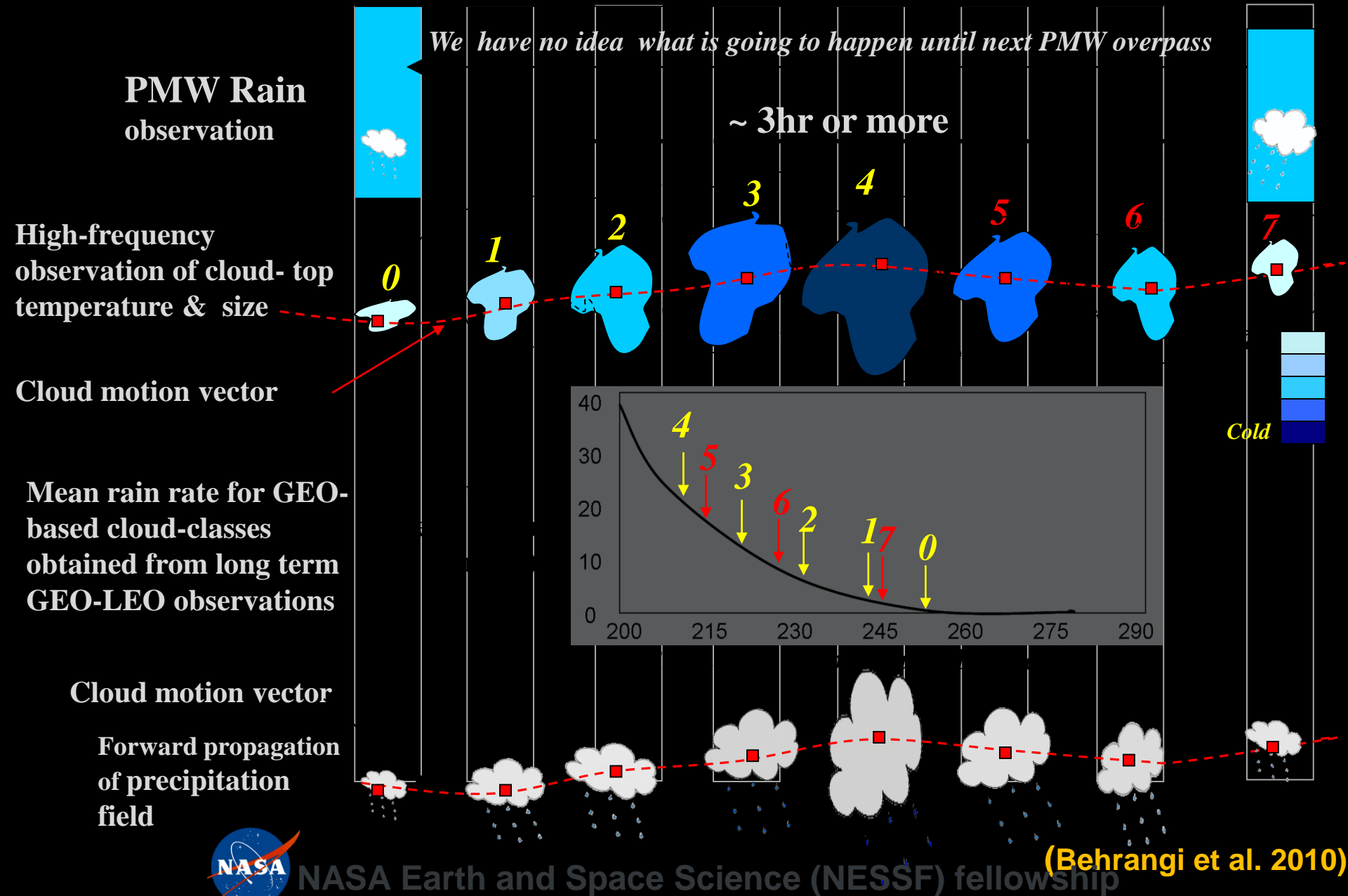
Typical maps of multi-sensor coverage of precipitation every 30 minutes



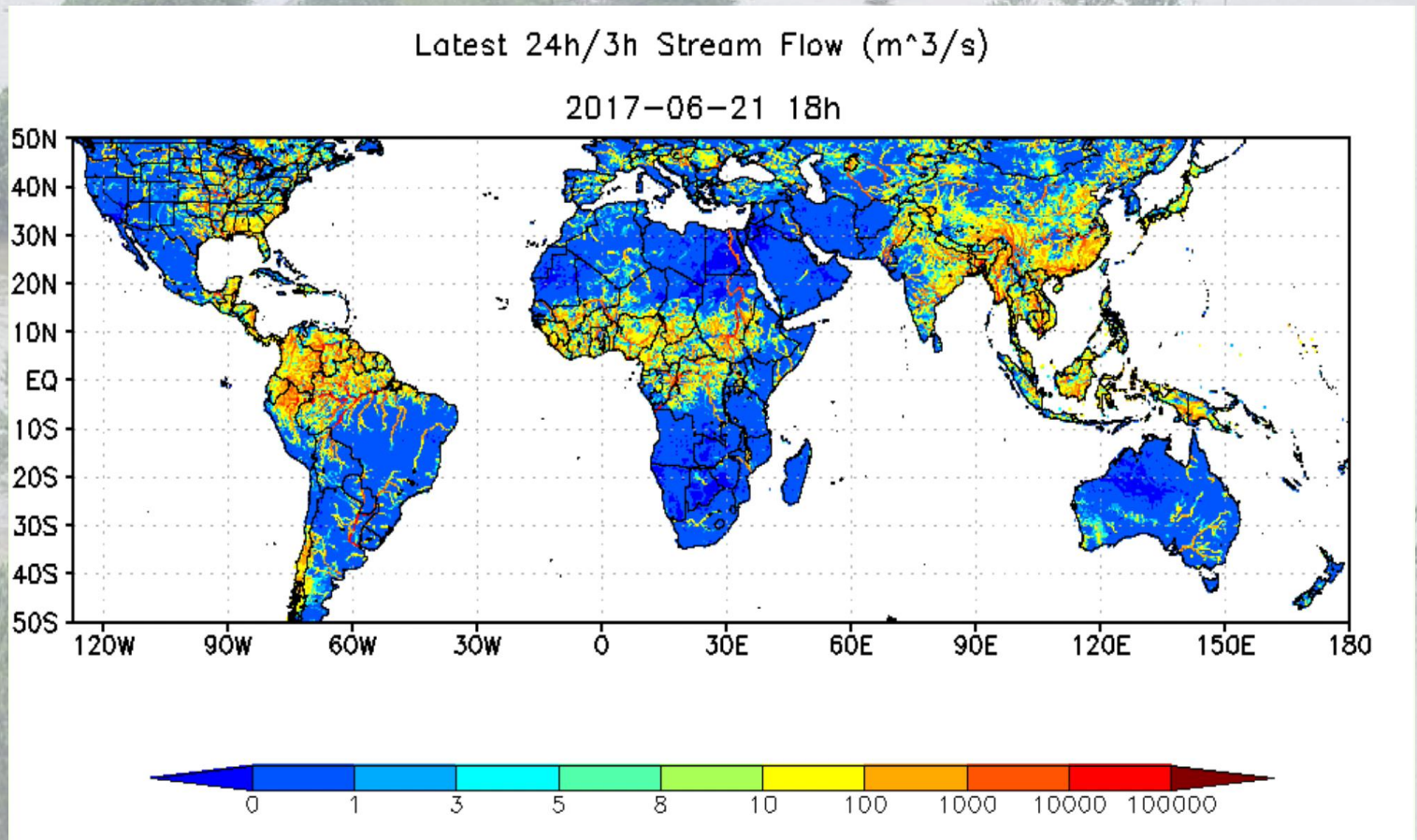
# Precipitation TEMPORAL resolution need for hydrology



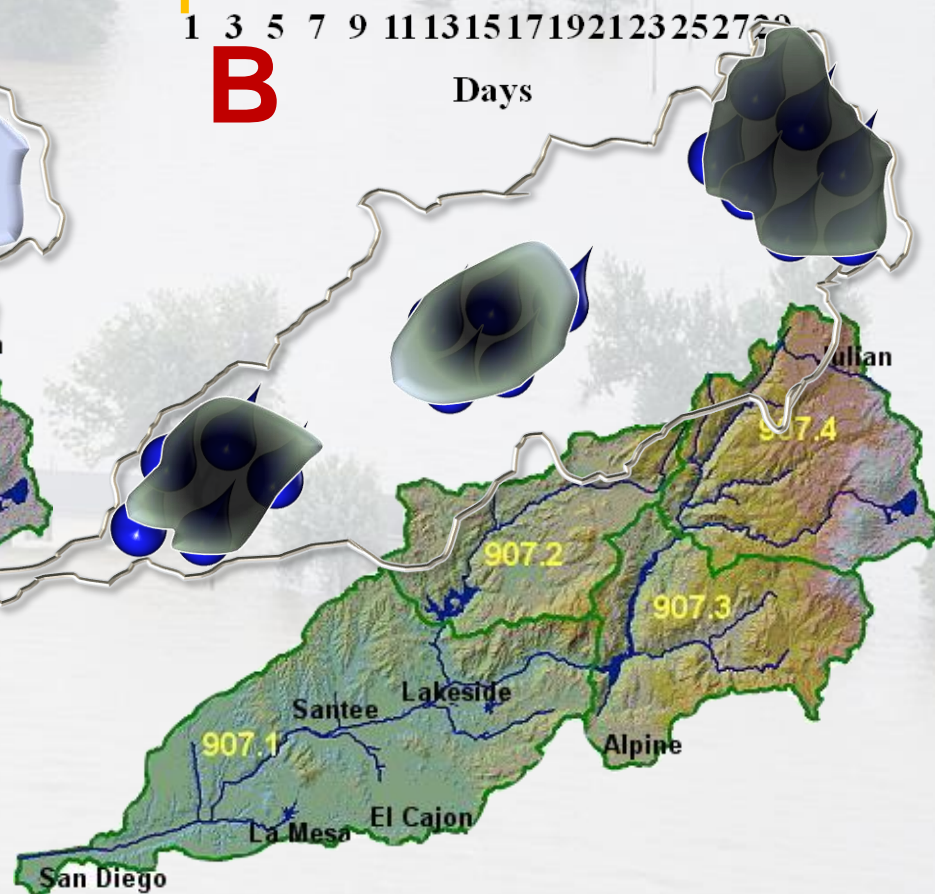
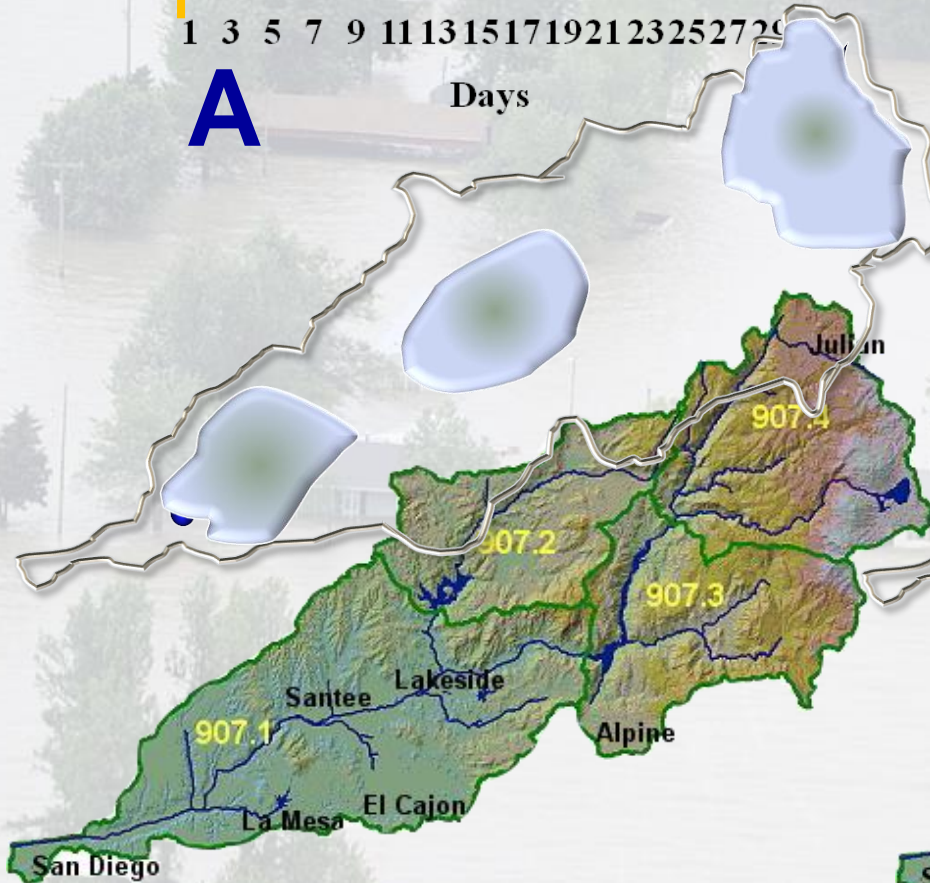
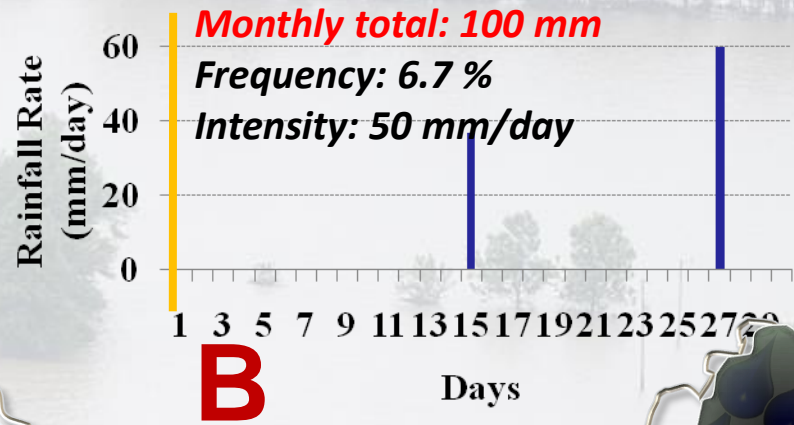
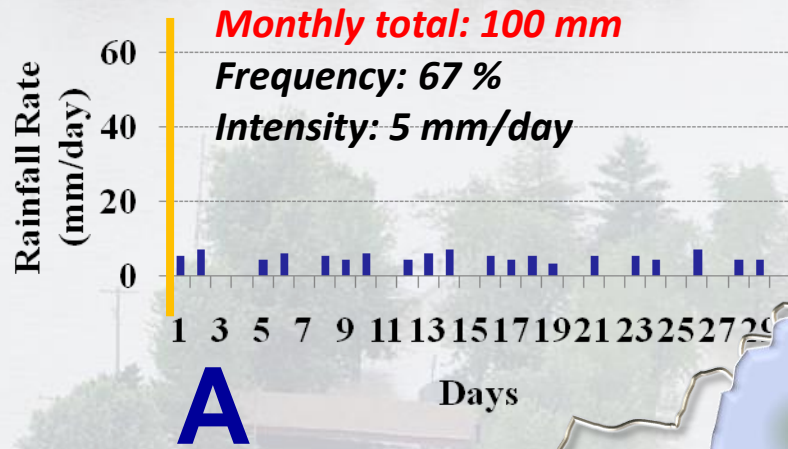
# REFAME: *Rain Estimation using Forward Adjusted Advection of Microwave Estimates*



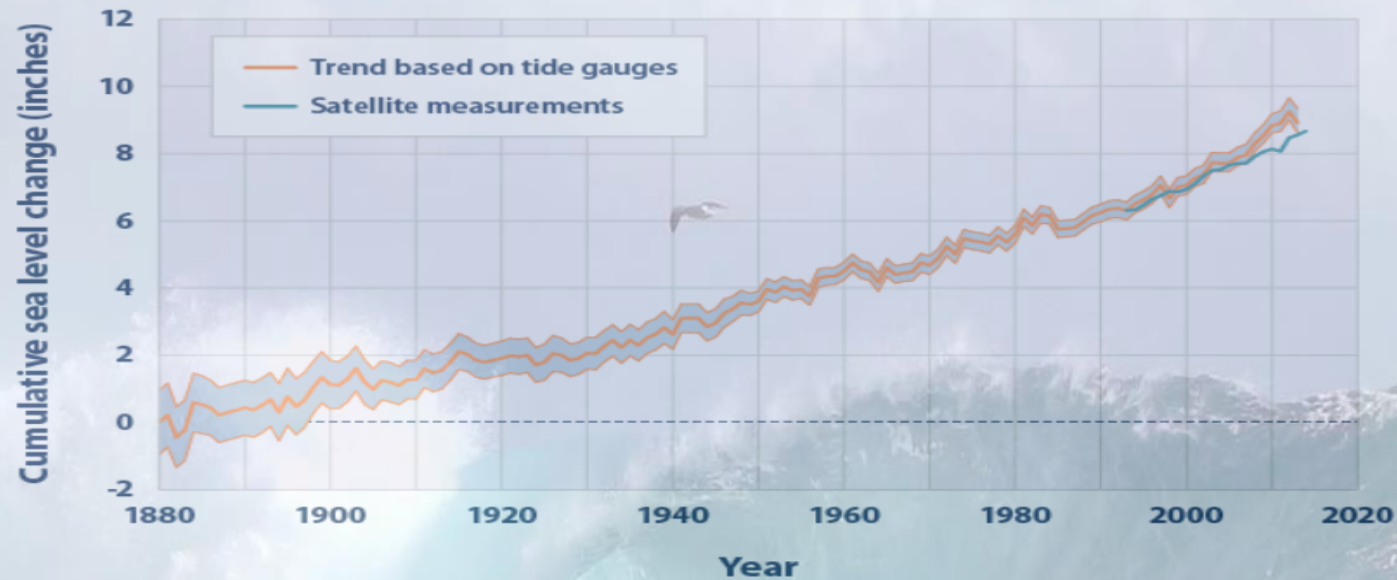
# FLOOD



# Rainfall less frequent more intense in future



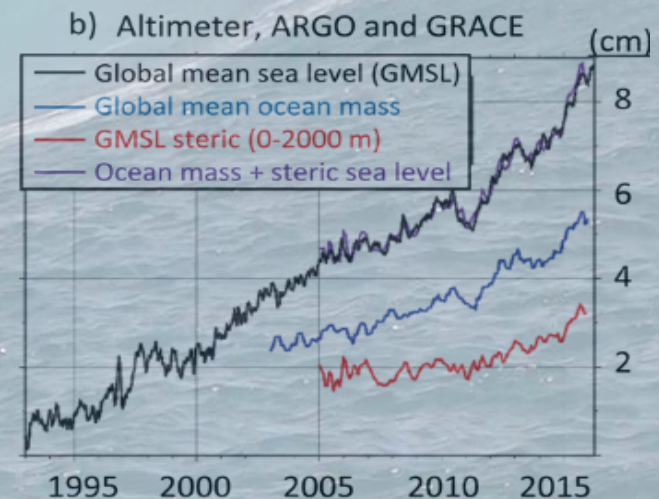
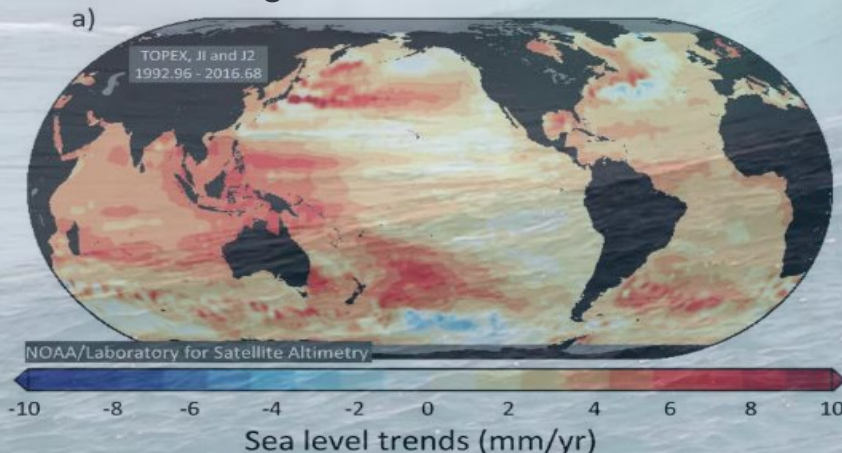
# Global sea level rise



Data sources:

- CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2015 update to data originally published in: Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. *Surv. Geophys.* 32:585–602.

See level change from 1992-2016 from satellites

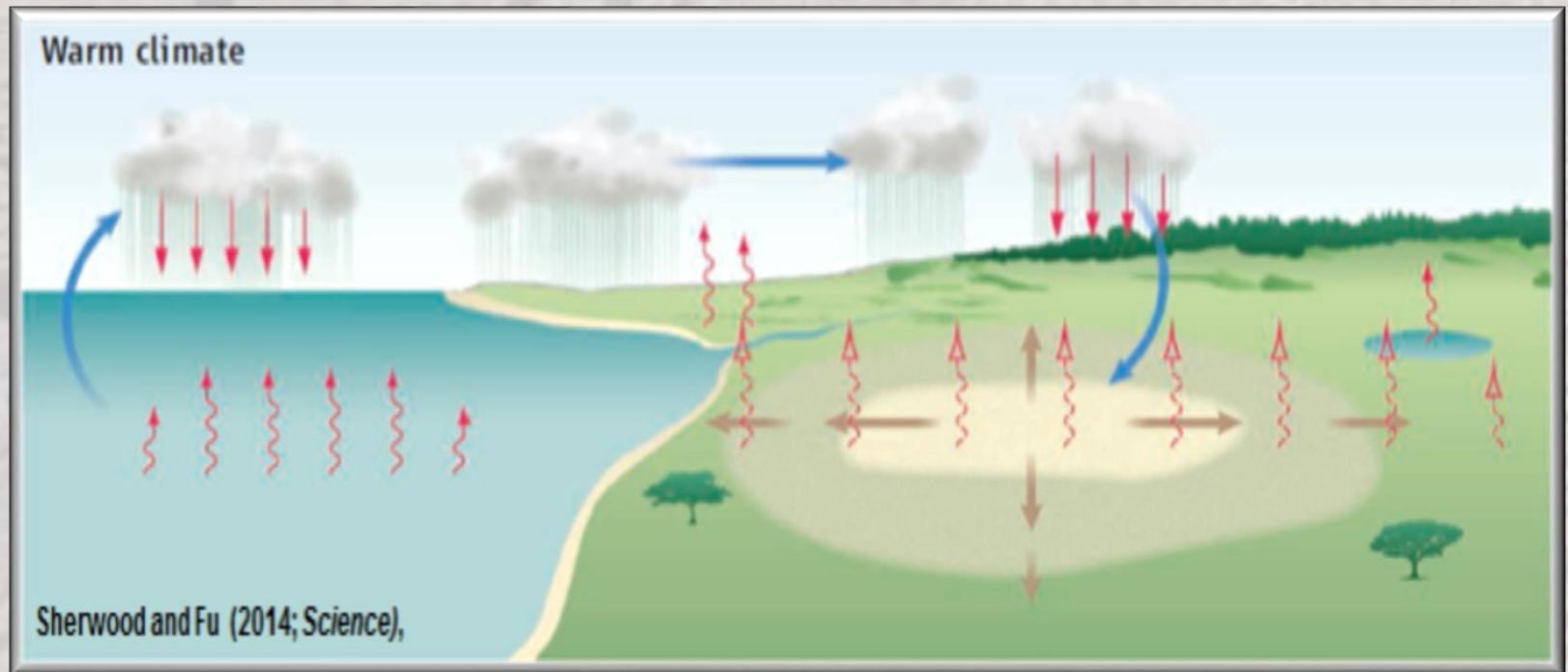


Reference: Global and Regional Sea Level Rise Scenarios for the United States, NOAA Technical Report NOS CO-OPS 083

A photograph of a dry, cracked landscape under a clear sky. The ground is parched and split into a mosaic of irregular, polygonal shapes. Several dead, bleached tree trunks and branches are scattered across the scene, some standing upright and others lying flat. In the background, a line of low, scrubby vegetation marks the horizon. The word "DROUGHT" is superimposed in large, bold, black capital letters on a semi-transparent white rectangular background in the upper-middle part of the image.

**DROUGHT**

- ❑ The Key factor in drying over land is that land surfaces (and the air just above them) warm, on average, about 50% more than ocean surfaces (M. Joshi et al. 2008)



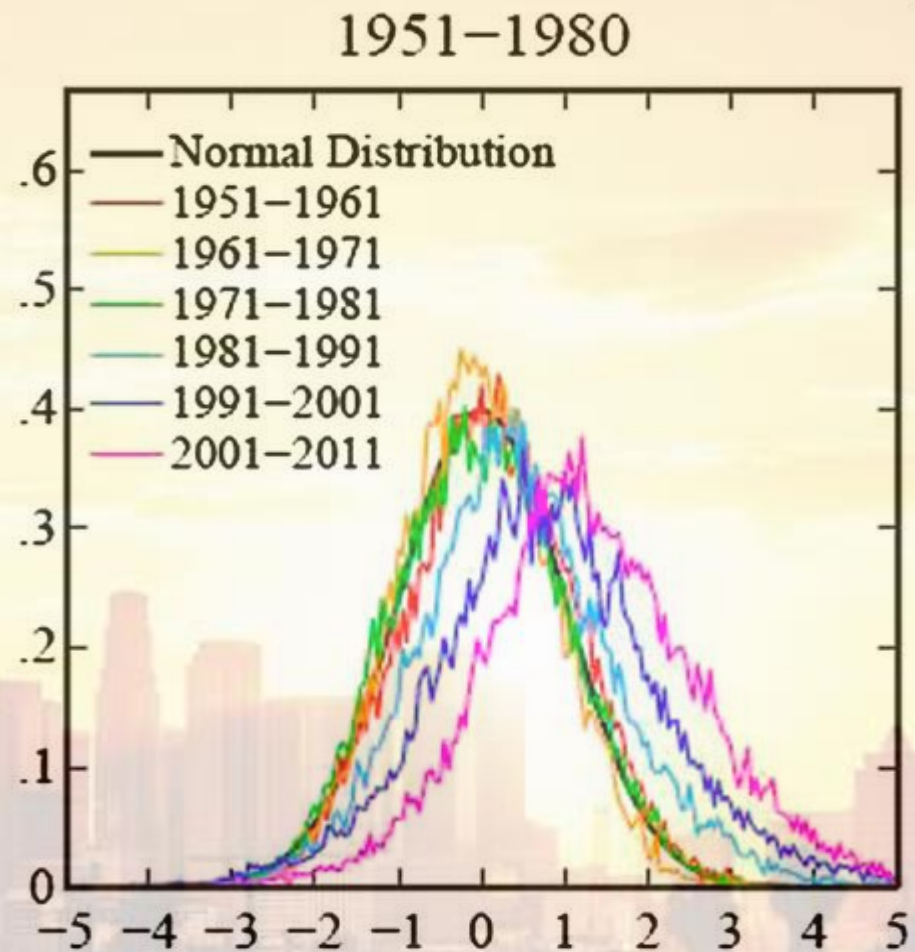
# Climate change alters the probability of extreme events

(a new normal)

Probability of summer temperature over all Northern Hemisphere land grid boxes (using 1951-1980 baseline)

[Hansen et al. 2012, *PNAS*]

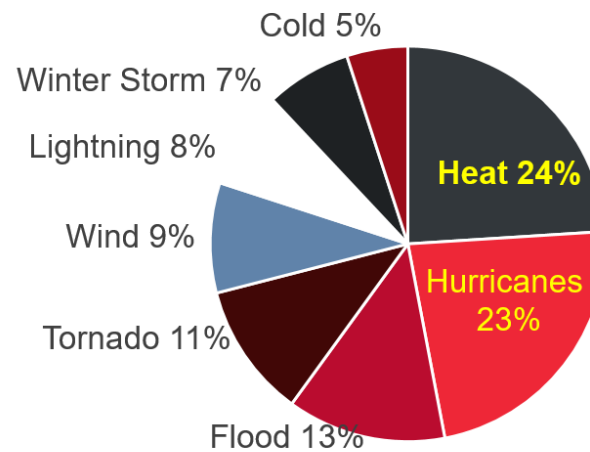
**Current temperature extremes will likely be normal in future**



Frequency of occurrence (Y axis) of local temperature anomalies (relative to 1951–1980 mean) divided by local standard deviation (X axis) obtained by counting gridboxes with anomalies in each 0.05 interval. Area under each curve is unity

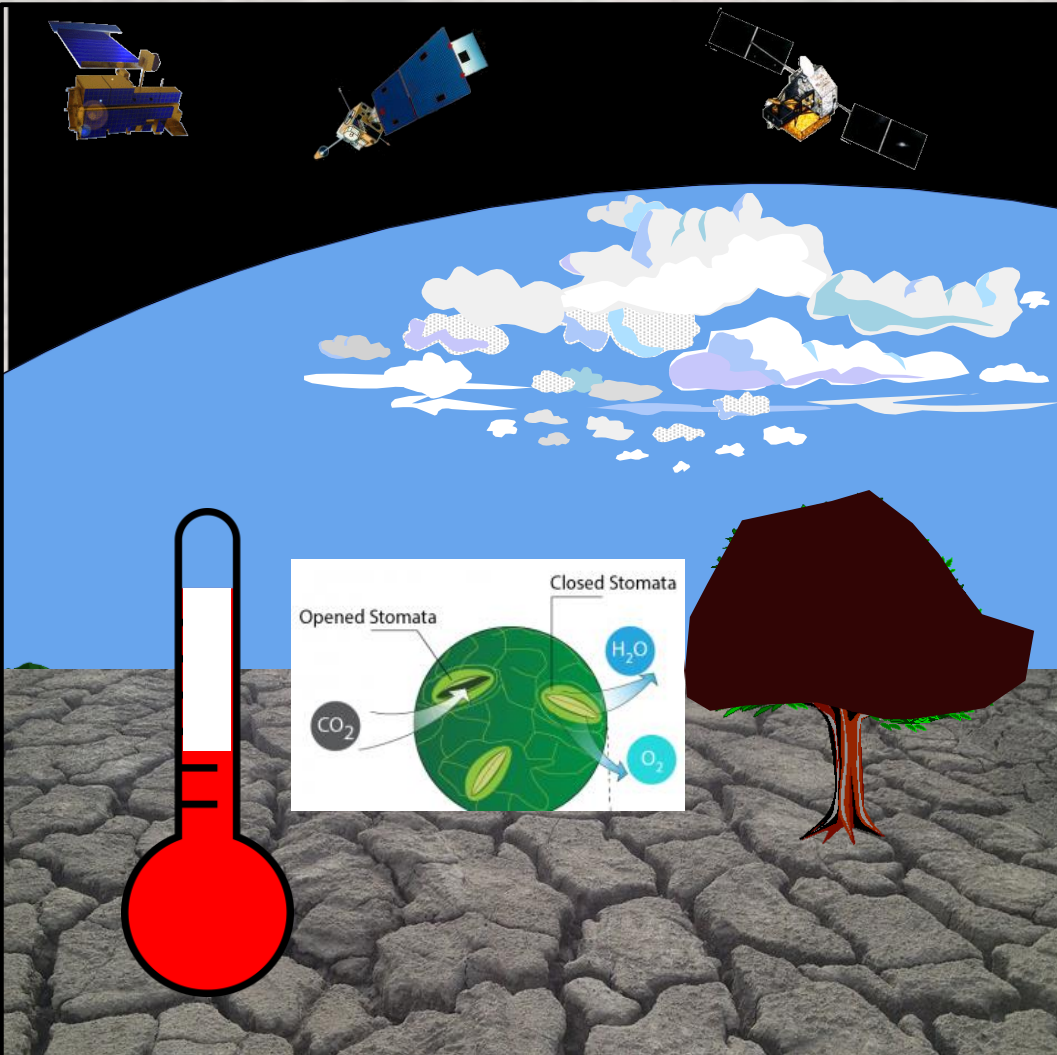
# HEAT

## U.S. Deaths Attributed to Weather Conditions 2000-2009\*



\*NOAA 2010 in  
<http://www.cdc.gov/climateandhealth/pubs/ClimateChangeandExtremeHeatEvents.pdf>

# Drought, Biosphere-land-atmosphere feedbacks



## Environment:

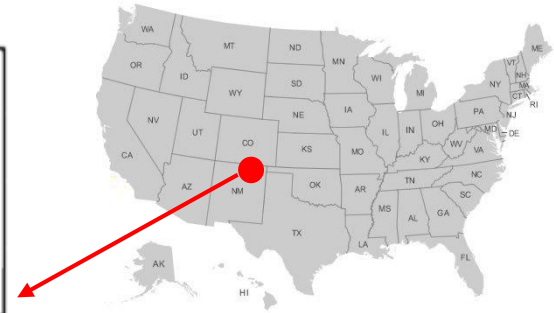
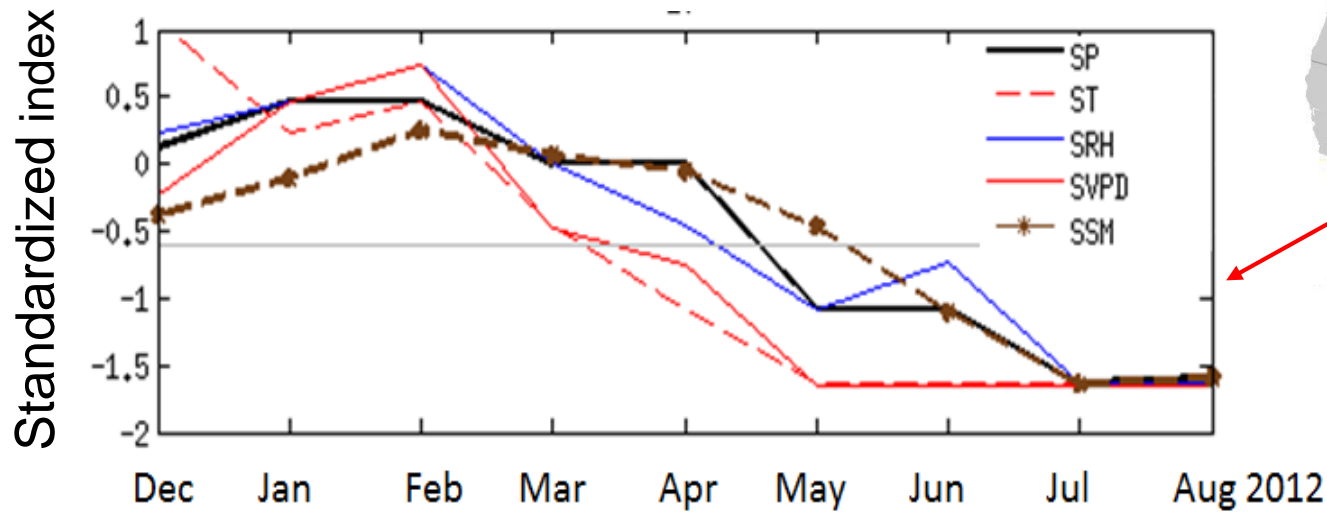
- $T \uparrow$   $RH \downarrow$   $VPD \uparrow$
- Precipitation  $\downarrow$
- Soil Moisture  $\downarrow$

## Vegetation:

- SIF  $\downarrow \downarrow$
- NDVI  $\downarrow$

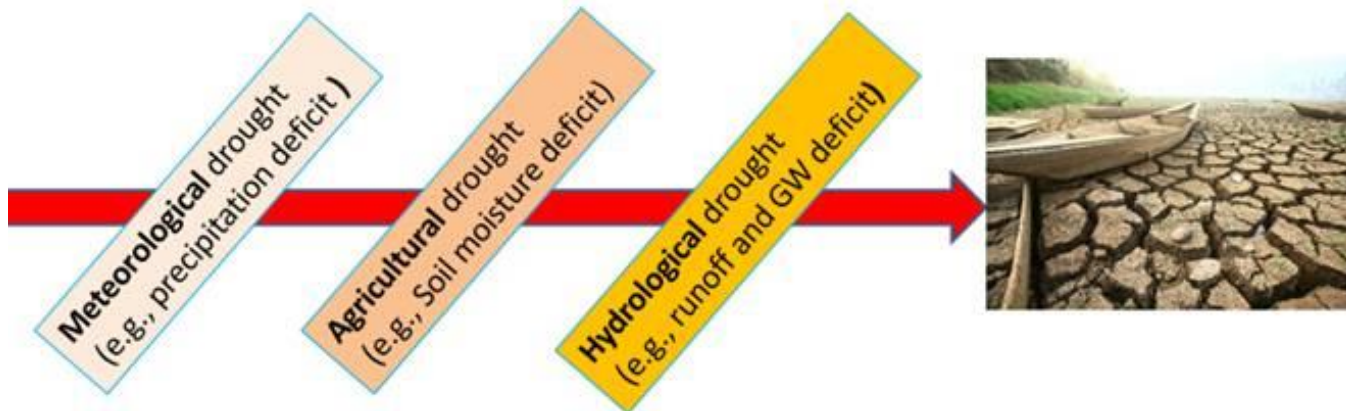
**SIF:**  
solar-induced chlorophyll fluorescence

# Early detection of drought onset

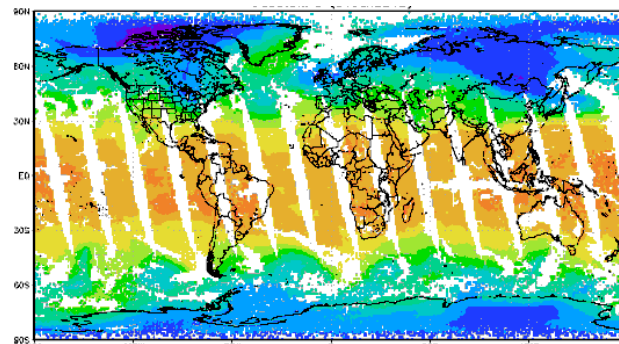
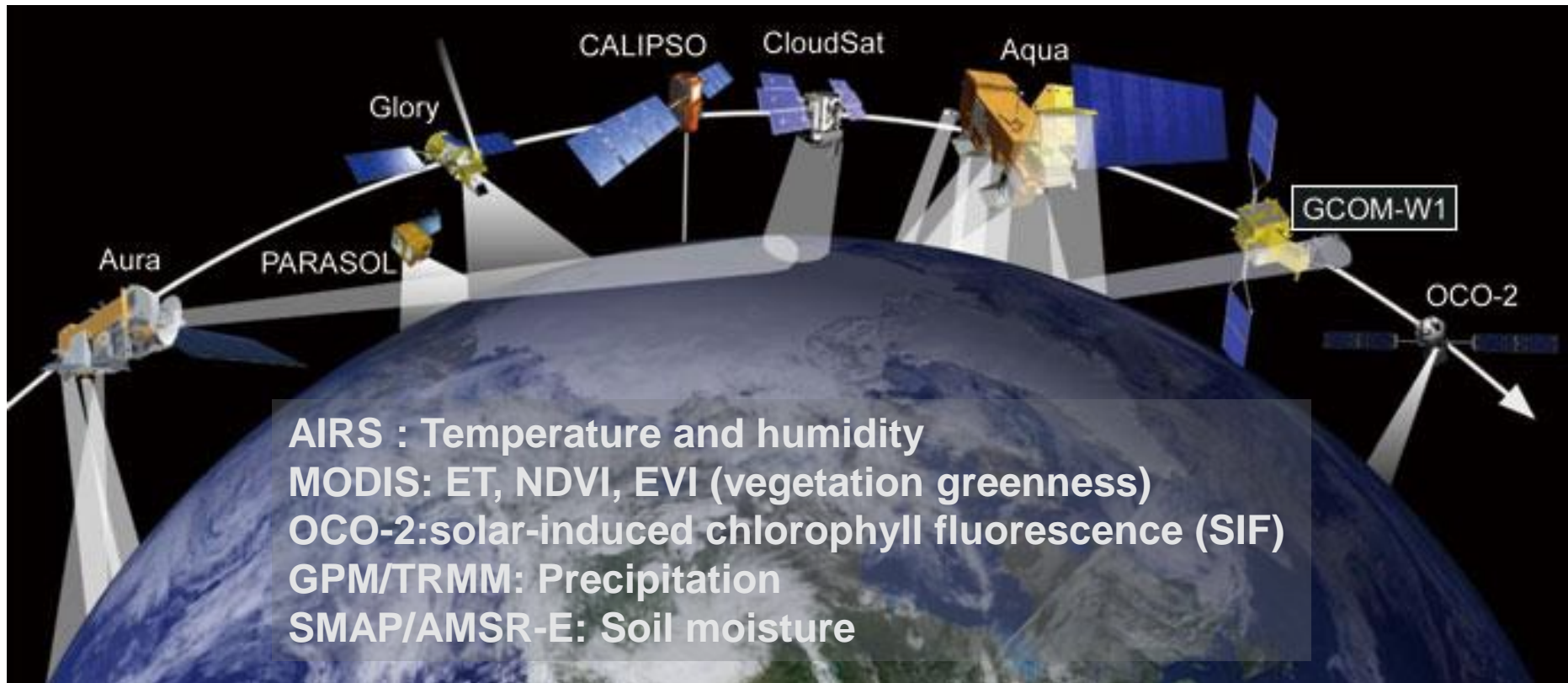
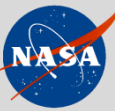


Behrangi et al. (2015, climate)

## Drought formation

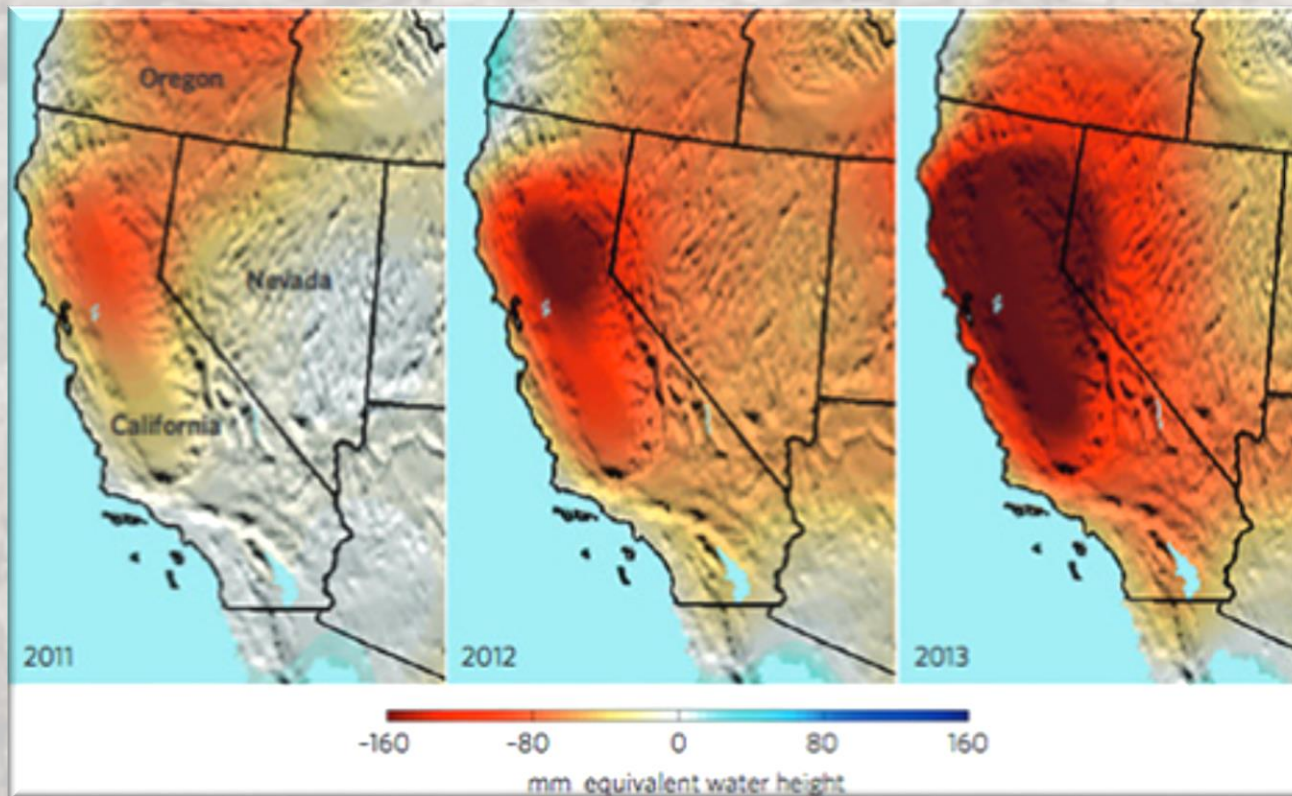
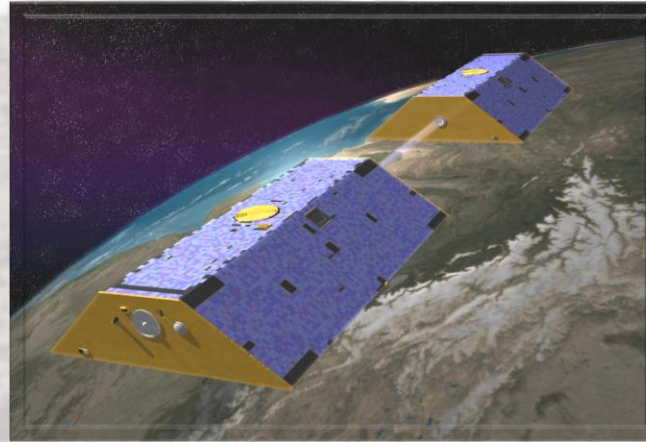


# Remote sensing of drought



# Global Monitoring Groundwater Depletion

NASA's Gravity Recovery and Climate Experiment (GRACE) satellite mission

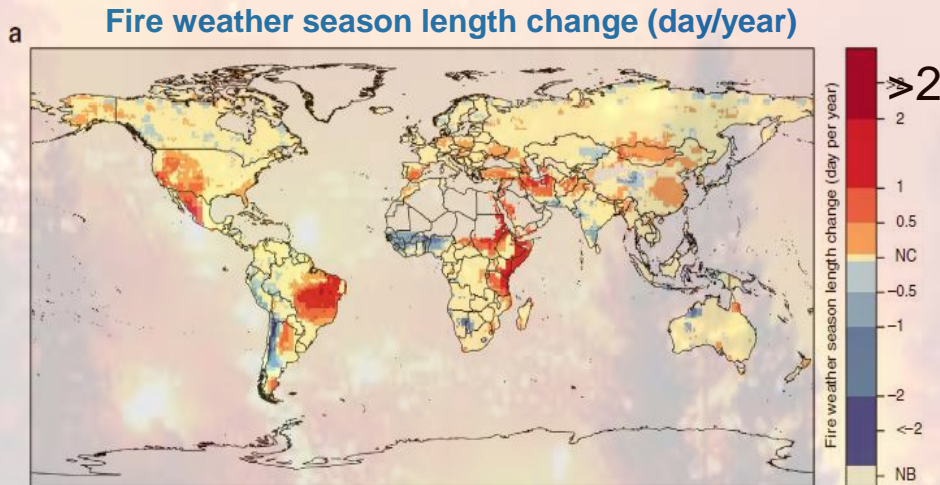


# FIRE

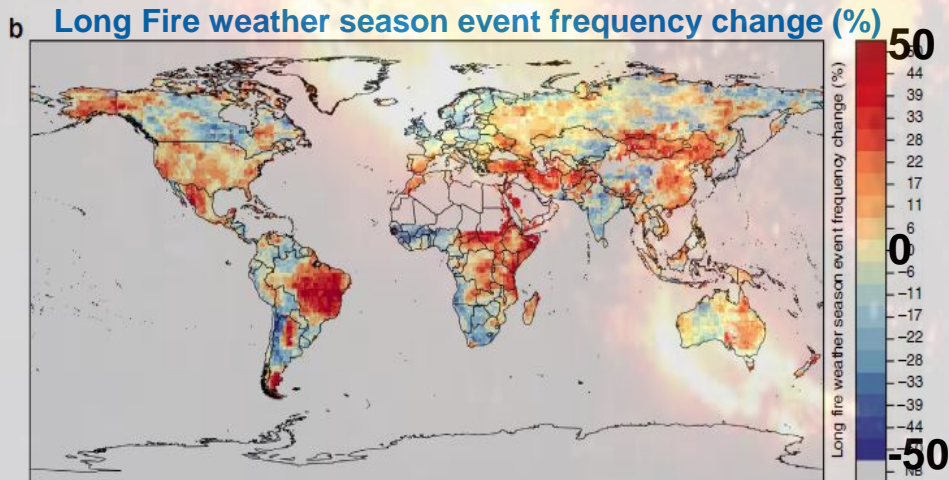
- ❑ Drought can cause and enhance fire
- ❑ Extra precipitation before fire season can also enhance fire occurrence and extent (more fuel more fire)



# Climate-induced variations in global wildfire danger from 1979 to 2013



□ 18.7% increase in global mean fire weather season length.

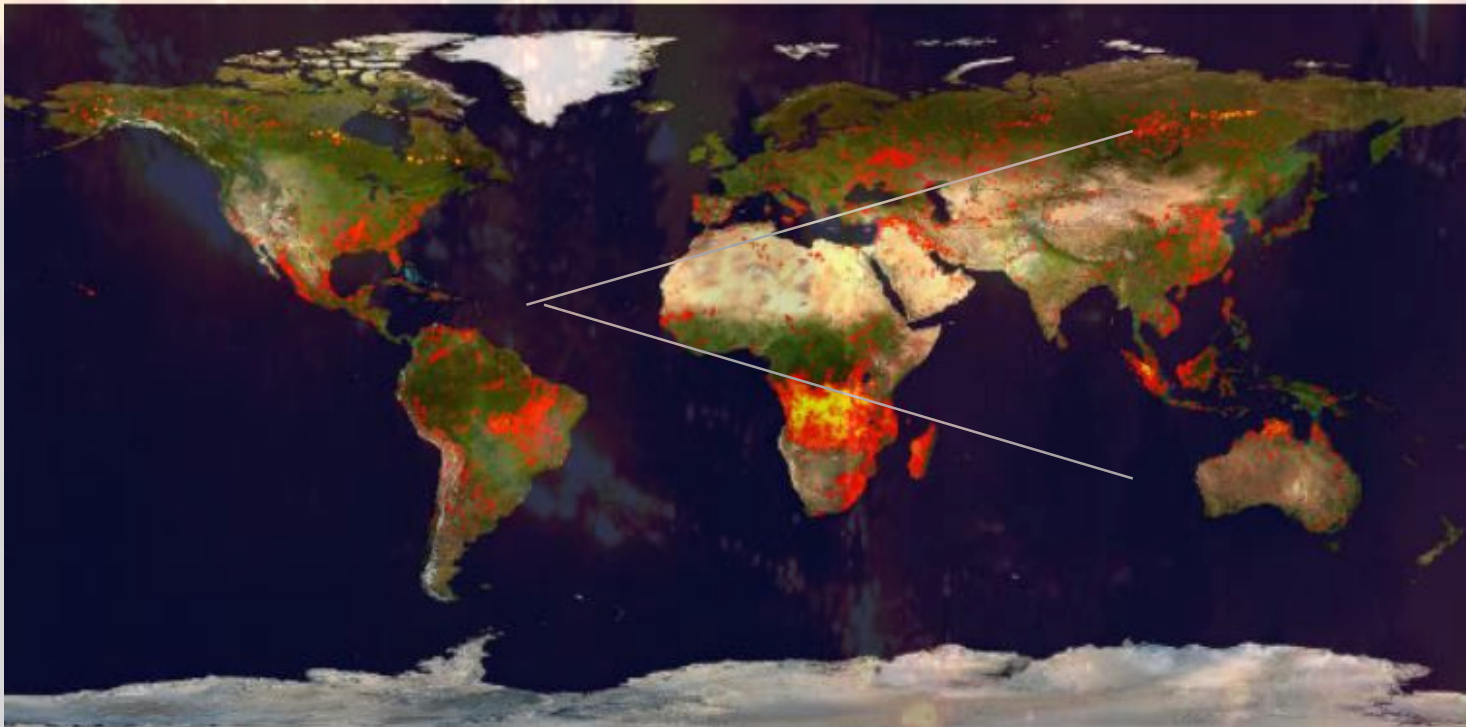


□ There is a doubling (108% increase) of global burnable area affected by long fire weather seasons.

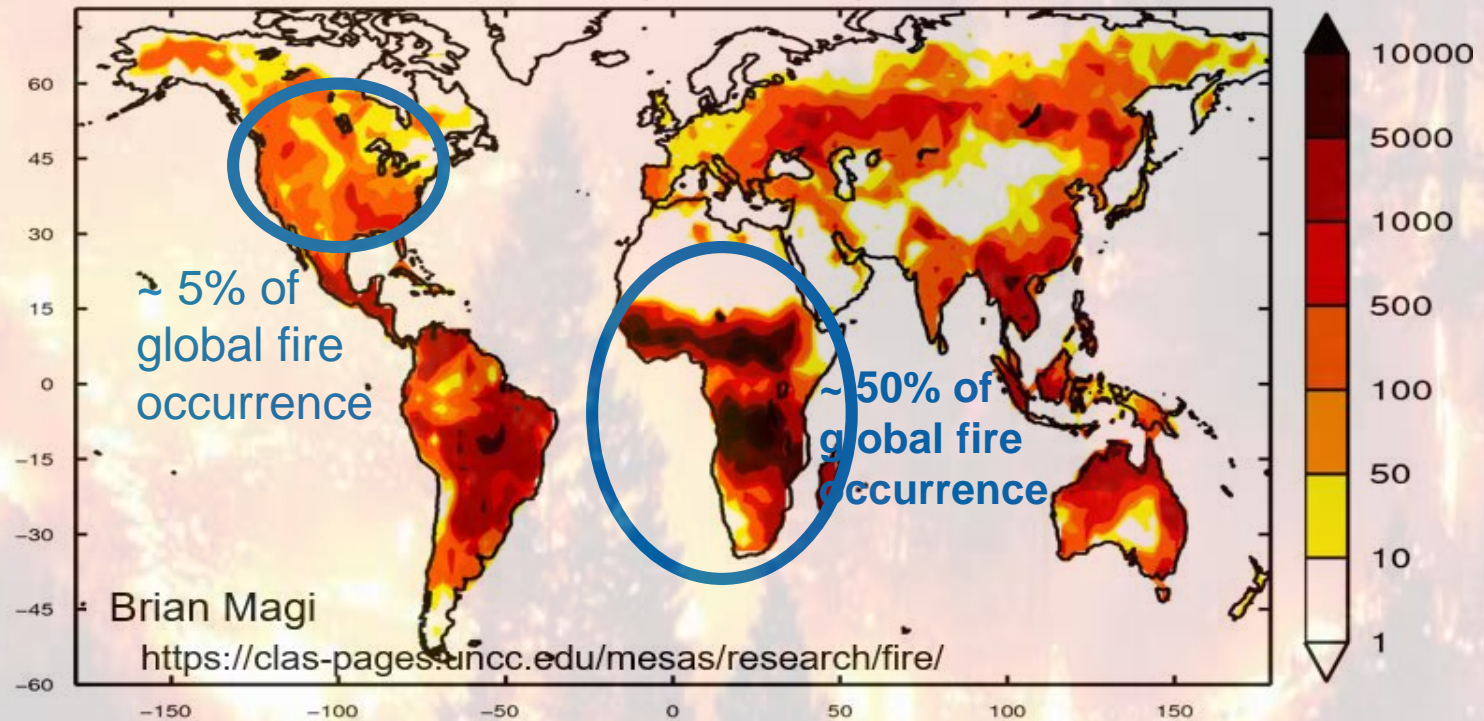
Used NCEP and ECMWF data to calculate burning and fire danger indices

# Detecting FIRE from space:

**NASA Moderate  
Resolution Imaging  
Spectroradiometer  
(MODIS)**



## Annual mean number of fires from 2000-2009



- ❑ The total number of fires that occur every year is between about 1.5-3.5 millions fires, according to satellite-based measurements from MODIS
- ❑ *Only about 4-5% of fires that occur on Earth every year occur in the USA. Nearly 75% of all fires occur in the tropics, **and about 50% occur on the continent of Africa alone***

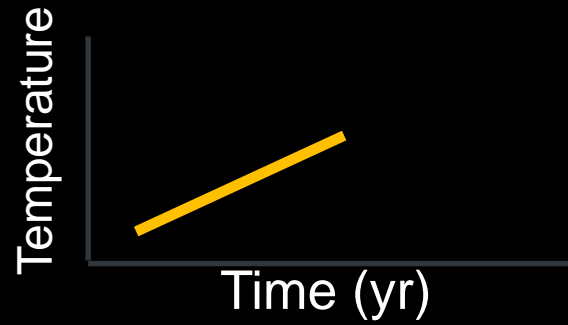


# Cascading and Interacting Natural Hazards

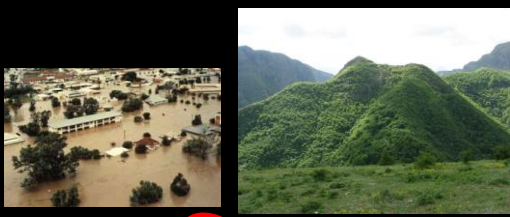
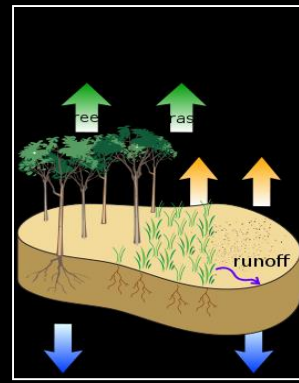


# Climate change & natural hazards: Interconnected processes

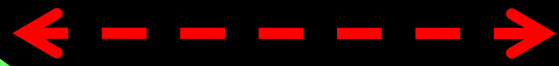
Climate change =>



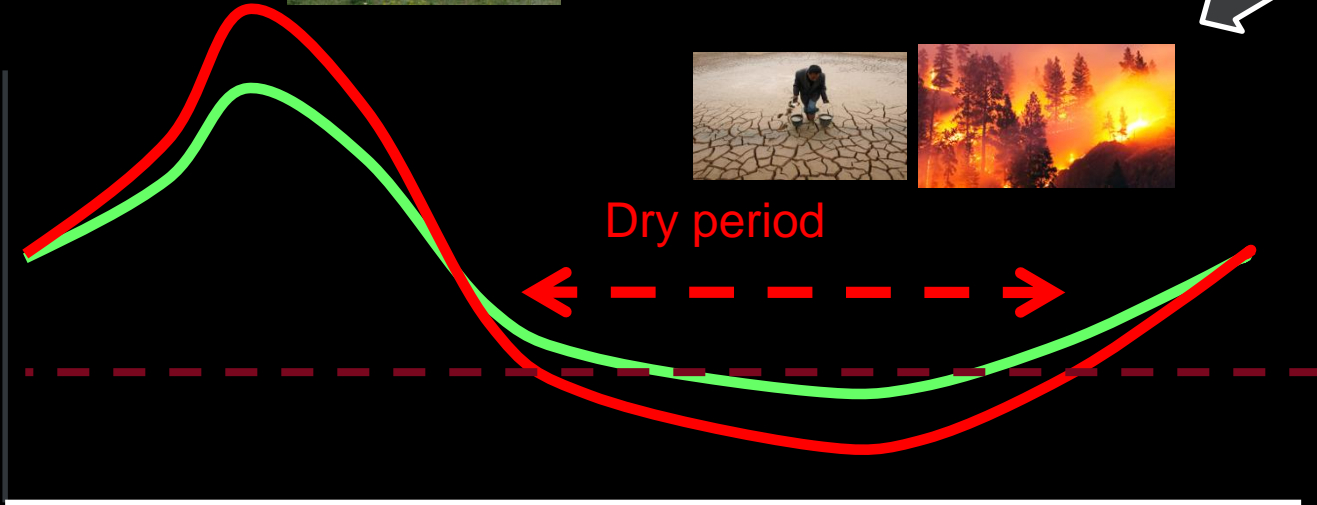
+



Dry period



Stream flow



Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec



So, it suggests that : Current climate “stationary” assumptions in our studies/designs need to be revised.